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DOUBLE THEODOLITE-ANEMOMETER WIND-MEASURING SET

Donald E. Johnson

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UNITED STATES ARMY
ELECTRONICS RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, N.J.

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Abstract

This report discusses the feasibility of combining a double theodolite wind-measurement with an anemometer wind-measurement, with the intent of having the combination form a practical wind-measuring system. The wind data from such a combination would be applied to the correction of a rocket-launcher setting before firing a free missile.

A theoretical discussion and supporting data are presented to show that this combination of equipment is not feasible for the formation of a practical system.

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CONTENTS

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INTRODUCTION

This report reviews the feasibility of combining a double theodolite wind measurement with an anemometer wind measurement in a way that would make the combination a practical wind-measuring system. The intent of such a combination is to obtain a more useful wind value from which to calculate the corrections which must be applied to a rocket-launcher setting before firing a free missile.

BACKGROUND

This possible approach to wind measurement was discussed during a conference on low-level winds held on 10 March 1959 at OCSigO. A letter from OCSigO dated 22 May 1959 authorized the development of a double theodolite-anemometer wind-measuring set. The Meteorological Division program for low-level winds, dated 8 July 1959, proposed a study to determine the feasibility of combining the two types of measurements in a useful low-level wind-measuring system. In August 1959 an investigation was begun, although on a low-priority basis. The project lay dormant for sometime until tests were completed with data taken on the wind range.

The possibility of combining a double theodolite observation with an anemometer wind measurement to determine rocket wind corrections had been under consideration for several years. This technique could not be reliably evaluated without data taken under laboratory conditions, where the limits of all variables were either known or could be determined. With the installation of the low-level wind range at USAEIRDL, such data requirements were satisfied, and the analysis of the techniques became a reality.

DISCUSSION

Theory

The accuracy with which a free missile can be launched so as to hit a predetermined target depends partly on the accurate prediction of the wind that the rocket will sense in its burning phase. Rockets are launched at various elevation angles in order to attain various ranges. Therefore the vertical layer of atmosphere which they will pass through while burning varies in thickness. It is generally accepted in meteorology that the mean wind speed in the lower few hundred feet of atmosphere normally increases with altitude. This property of the wind requires that the value of wind speed used in conjunction with a given launching shall normally vary with the elevation angle at which the rocket is fired. The fixed-height type of anemometer now used as standard equipment does not have the variable height capability which is desirable. In order to overcome the fixed-height limitation of the anemometers that are used in the field as rocket launching accessories, tables have been supplied from which a correction may be obtained and applied to the anemometer reading. This correction allows for

winds to the height at which a particular rocket will burn out if fired at a given elevation setting, and for the response characteristics of the rocket.

The increase of wind with altitude in the first few hundred feet of height is often expressed by the following mathematical equation:

$$W = kz^p,$$

where

W = wind speed,
z = altitude,
p = wind-profile index.

The profile factors presently used with fixed-height equipment to predict the wind at an altitude other than that of the anemometer have been empirically derived. In practice, an estimate of wind profile is obtained by observing the weather situation prior to the launching of a rocket. If a live (nonestimated) profile factor could be obtained directly from wind measurements made just prior to launch time, a valuable bit of data would be added to the present method of obtaining winds above a fixed height.

The double theodolite wind-measuring method can measure winds in the layers of atmosphere which are of concern to the rocket-launching problem. The variable height capability of the theodolite method would seem to make it a possible way of obtaining live profile factors. However, balloon tracking can be erratic in the lowest altitudes. It seems that an advantage could be gained by combining the anemometer and balloon methods so that the anemometer reading is substituted for the lowest part of the balloon-sensed wind. However, the gusty, turbulent nature of low-level winds would seem to preclude the existence of a wind profile index in the live sense. If the wind profile is to exist at all, the nature of wind indicates that it would have to be in a statistical sense, with wind samplings averaged over at least 30 minutes of time.

Pursuing the possibility of obtaining a live profile, the wind measured by the anemometer at a fixed altitude z_o is expressed as

$$W_{zo} = kz_o{}^p.$$

The average wind in an altitude layer 0 to z_1, as sensed by a rising balloon, is expressed as

$$\bar{W}_{z_1} = \frac{\int_0^{z_1} F(z)\ W(z)\ dz}{\int_0^{z_1} F(z)\ dz} .$$

In this expression,

$$W(z) = kz^p,$$

and $F(z)$ is the wind-influence function. For a small pilot balloon,

$F(z) = 1$ is assumed. Therefore,

$$\overline{W}_{z_1} = \frac{k \int_0^{z_1} z^p \, dz}{z_1}$$

$$= k \frac{z_1{}^p}{p + 1} .$$

If the anemometer measures to a height of z_o, and the balloon is tracked to a height of z_1,

$$\frac{\overline{W}_{z_1}}{W_{z_o}} = \frac{1}{p + 1} \left(\frac{z_1}{z_o}\right)^p .$$

In this relationship the only unknown is the profile factor p. Therefore, the measurement of a live profile seems possible, but the wind speed and balloon height would have to be known with sufficient accuracy. Assuming no error in tracking to the required altitude, and assuming wind speed can be measured to ±1 mph by both the anemometer and the balloon, the examination of a hypothetical wind situation will reveal whether a practical wind-measuring combination can sense a live (single-measurement) profile.

If the fixed anemometer is at 50 feet and the balloon position is read when it reaches a height of 300 feet, the balloon-integrated wind is assumed to be 11 mph and the anemometer wind is assumed to be 9 mph. Using the wind ratio equation pertinent to the double theodolite-anemometer combination and applying it to the assumed conditions, a wind profile of 0.22 must exist. The wind-measuring accuracy of the combination components will allow the ratio of the two wind measurements to vary between a maximum of

$$\frac{\overline{W}_{z_1}}{W_{s_o}} = \frac{11 + 1}{9 - 1} = 1.5$$

and a minimum of

$$\frac{\overline{W}_{z_1}}{W_{z_o}} = \frac{11 - 1}{9 + 1} = 1.$$

The profile values corresponding to these extreme ratios are 0.42 maximum and zero minimum. If it were possible to measure wind profile with a single measurement from an anemometer and double theodolite, these equipments are not accurate enough to sense the profile.

The purpose of a profile measurement is to calculate wind at any desired altitude in the lower layers from a wind measurement made at a fixed height. Using the wind profile 0.2'. of the hypothetical case, the wind calculated for 300 feet would be

$$W_{300} = kz^p = 13.3 \text{ mph.}$$

But with the profile (p) varying from 0 to 0.42 with equipment accurate to ±1 mph, the 300-foot wind reading could vary from 9 mph to 19.2 mph. These figures point out the insensitivity of the double theodolite-anemometer combination to the measurement of wind profile, at least for the hypothetical example calculated. The condition deteriorates for lower wind speeds and improves slightly as wind speeds become higher. However, the equipment accuracy of ±1 mph used for this examination of a hypothetical wind was optimistic. The double theodolite equipment may approach this accuracy under conditions of level terrain and small wind gradients, but the fixed anemometer accuracy is not as good as ±1 mph.

If a one-run profile measurement were attempted by taking two readings on a balloon flight, the following ratio equation would obtain:

$$\frac{\overline{W}_{z_2}}{\overline{W}_{z_1}} = \frac{\dfrac{\int_0^{z_2} F(z)\, W(z)\, dz}{\int_0^{z_2} F(z)\, dz}}{\dfrac{\int_0^{z_1} F(z)\, W(z)\, dz}{\int_0^{z_1} F(z)\, dz}} = \left(\frac{z_2}{z_1}\right)^p .$$

Again assuming an optimistic ±1 mph for the balloon-integrated winds, the wind profiles calculated from the measurements would vary so as to lack sensitivity for the existing wind conditions. For example, assume that the balloon position is read at heights of 150 feet and 400 feet, and assume the wind to 150 feet is 8 mph and the wind to 400 feet is 10 mph. The profile index determined by these values is 0.23. However, the system inaccuracies assumed would allow the profile to vary from a minimum of zero to a maximum of 0.46, so calculation of the wind at 400 feet from the true wind at 50 feet could vary from 7.6 mph to 20.0 mph, when the true value at 400 feet should be 12.4. Again, a single reading is insensitive for the calculation of a wind profile, if such a nonstatistical profile existed. Here, again, the assumption of an accuracy of ±1 mph was an optimistic one. This is especially true for the lower balloon reading.

The live-profile approach is not feasible for two reasons. First, the profile concept probably exists only in a statistical sense; and secondly, if it did exist in the live sense it could not be detected with any degree of accuracy by either a practical double theodolite-anemometer combination or by a balloon flight alone.

Neither does the substitution of an anemometer reading for the lower part of a balloon flight look promising. If a wind is measured by an anemometer at a height z, so that

$$W_z = kz^p,$$

there is an equivalent wind integrated by a balloon to a height z_2 such that

$$W_{z_1} = \bar{W}_{z_2} = \frac{k\ z_2^{\ p}}{p + 1} = kz_1^{\ p}$$

or

$$z_2 = z_1\ (p + 1)^{\frac{1}{p}}.$$

Therefore, the height z_2, which must be known so that all of the balloon flight below it may be eliminated, depends on profile p, which probably does not exist in a live sense. Even if the height z_2 were precisely known, it would be difficult to measure because it would depend on balloon-flight time and the rate of rise of the balloon. The rate of rise of a tactical system will vary by at least ±10%.

Tests

Experiments were run from which some of the theory discussed could be tested. One of the most fruitful of these tests was a series of balloon flights which were tracked by phototheodolites. These flights consisted of 15 balloons released at 2-minute intervals. Phototheodolite readings were attempted every 2 seconds for the first 80 seconds of each balloon release. The programmed print-out from the raw data of these flights provided much data with which to test some of the points discussed under "Theory." (See the appendix for a sample print-out of a complete balloon flight.)

Data were taken on the USAEIRDL wind range simultaneously with the phototheodolite data. This wind range is a series of poles and towers arranged in line so that the tops simulate the initial part of a rocket trajectory. Anemometers are mounted on the tops of the poles and towers. The anemometer on the 50-foot pole was used to represent a fixed-height anemometer in a double theodolite-anemometer wind-measuring system.

Profiles were calculated by using appropriate data from the 50-foot anemometer and the integrated wind, measured by a balloon rising to 300 feet and tracked by a double phototheodolite setup. The results are tabulated in table 1.

The flights shown in this table are of 30-minute duration, and each run in the flights is 2 minutes apart. The profiles are calculated from single wind readings during a run. (This type of calculation was called a "live" profile in the "Theory" section of this report.) The wide dispersion of profile fractions, which represent wind conditions only two minutes apart, verifies the statement that profiles do not exist in the live sense and/or the statement that standard wind equipment cannot sense a profile.

Profiles were also calculated from the double phototheodolite balloon data, using winds resulting from a balloon reading as the balloon rose first to 150 feet and then on to 400 feet. Table 2 shows the results.

Table 1. Anemometer-Balloon Profiles

Run	Flight 1	2	5	10	11	13
1	.26	--	-.17	--	--	.05
2	.35	-.09	.59	.47	--	-.24
3	.21	.47	.74	-.11	.43	-.05
4	.03	.21	.37	--	.13	.63
5	.91	.50	--	--	.12	.12
6	--	--	--	.26	.54	.41
7	.72	--	.07	.11	.09	.23
8	.75	.43	.17	.45	.15	.13
9	.46	.48	-.11	.55	.53	-.16
10	.43	.50	--	.06	.21	.49
11	.51	--	-.75	-.37	-.13	--
12	.41	--	-.12	.06	.40	--
13	.65	--	-.22	-.10	.23	--
14	.84	--	.22	--	-.04	--
15	--	--	.67	--	--	--

Table 2. Profiles from Balloon Readings

Run	Flight 1	2	5	10	11	13
1	.29	--	.18	--	--	.01
2	.20	.32	-.03	.10	--	.08
3	.57	.32	-.13	.05	.29	.11
4	.04	.73	.02	--	.42	.22
5	.08	.17	--	--	.27	.06
6	--	--	--	--	--	-.02
7	.04	.40	.36	.42	.20	.12
8	.16	.45	.36	.16	.12	.17
9	.46	.31	.26	--	.08	.24
10	.34	.37	--	.17	.15	.20
11	.20	--	0	.17	.37	.46
12	.16	--	.18	.02	--	--
13	.22	--	.13	.54	.66	--
14	.09	--	.15	--	.33	--
15	--	--	.12	--	--	--

Data were also averaged over the 30-minute flight time, and wind profiles were calculated by the anemometer and balloon method and by the two readings on a balloon method. The results are tabulated in table 3.

Table 3. Averaged Profiles

Flight	50' anemometer and 300' balloon	150' balloon and 400' balloon
1	.50	.19
2	.23	.31
5	.13	.10
10	.14	.17
11	.26	.29
13	.19	.09

These are statistical wind profiles obtained over a 30-minute period from 15 sets of wind-speed values. Flights 5, 10, and 11 show good results, but the other three flights indicate that the averaging time might be too short to obtain closer agreement in profile index.

Balloons for the flights were inflated so as to attain a rate of rise of 7 feet per second. The nature of the tests and the limited number of personnel available made it necessary to inflate all balloons for a particular flight ahead of time. This meant that the last balloon in a flight (No. 15) had been inflated for over 30 minutes.

Tests for the consistency of rate of rise were made for flight times of 30 and 50 seconds. The 30-second balloons should have reached 210 feet. A sample of 66 balloons indicated that the average difference from this height was -3.6 feet, but the standard deviation of the rate of rise was 1.6 feet per second. The altitudes of the 50-second balloons were compared to 350 feet. A sample of 55 balloons was found to differ from this height by -13.2 feet. The standard deviation of their rate of rise was 1.3 feet per second.

CONCLUSION

It is not feasible to combine the double theodolite and anemometer into a wind-measuring system to provide more timely, useful data for the correction of a rocket launcher for wind effects.

REFERENCE

Barichivich, A. C., et al, "Double Theodolite Wind-Measuring Set for Rockets," USASRDL Technical Report 2019, 15 Mar 59.

APPENDIX

Sample Print-Out of a Complete Balloon Flight

DAY,MONTH AND HOUR 15111440 FLIGHT 1 RUN 1

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
12.0	162.060	9.325	63.601	28.408	93	83	83	7	7	112	62	6.4	3.5	6.4	3.5	1.3	.7
14.0	161.426	10.866	65.836	30.263	104	98	15	8	7	119	66	2.5	1.4	5.8	3.2	1.4	.7
16.0	159.218	12.155	69.786	30.931	118	112	15	7	7	135	83	5.4	5.7	5.8	3.5	1.6	.9
18.0	157.253	13.625	73.186	32.108	135	129	17	9	7	151	98	5.5	5.3	5.7	3.7	1.7	1.1
20.0	155.396	14.671	77.403	32.575	151	145	16	8	7	173	113	7.5	5.0	5.9	3.9	2.0	1.3
22.0	153.821	15.433	80.943	32.646	164	158	13	7	7	195	126	7.3	4.5	6.0	3.9	2.3	1.5
24.0	152.141	16.153	83.908	32.525	178	172	14	7	7	217	141	7.5	5.2	6.2	4.0	2.5	1.6
26.0	150.620	16.985	85.805	32.633	193	187	15	7	7	235	156	6.2	5.1	6.2	4.1	2.7	1.8
28.0	149.396	17.716	88.043	32.871	208	202	15	8	7	256	169	7.1	4.3	6.2	4.1	2.9	1.9
30.0	148.640	18.485	90.158	32.430	215	218	16	8	7	275	177	6.5	2.8	6.2	4.0	3.1	2.0
32.0	146.791	19.338	92.773	33.251	246	240	23	11	8	309	199	11.5	7.4	6.6	4.2	3.4	2.2
34.0	145.875	19.858	94.565	33.308	262	256	16	8	8	332	211	8.0	4.1	6.7	4.2	3.6	2.3
36.0	144.431	20.718	96.163	33.460	286	280	24	12	8	362	231	10.1	6.8	6.9	4.4	3.8	2.4
38.0	143.476	21.183	97.305	33.386	302	296	16	8	8	384	245	7.7	4.9	6.9	4.4	3.9	2.5
40.0	142.875	21.705	98.643	33.626	319	313	17	9	8	407	255	7.7	3.5	6.9	4.4	3.9	2.5
42.0	142.163	22.183	99.593	33.730	336	330	17	8	8	428	267	7.2	4.1	7.0	4.3	4.0	2.5
48.0	139.630	24.276	101.660	34.705	405	398	69	11	8	498	314	7.9	5.3	7.1	4.5	4.0	2.5
50.0	139.103	24.653	102.091	34.835	420	414	15	8	8	514	325	5.7	3.7	7.0	4.4	4.0	2.5
52.0	138.601	25.018	102.461	34.953	435	429	15	8	8	530	335	5.4	3.6	6.9	4.4	4.0	2.5
54.0	138.125	25.388	102.808	35.093	450	444	15	8	8	546	346	5.4	3.6	6.9	4.4	4.0	2.5
56.0	137.760	25.941	103.608	35.486	474	467	23	12	8	569	356	7.9	3.5	6.9	4.3	4.0	2.5
58.0	137.803	26.375	104.386	35.915	490	484	17	8	8	584	358	5.2	.7	6.9	4.2	4.0	2.5
60.0	137.430	26.970	104.528	36.403	510	503	19	10	8	596	367	3.9	3.0	6.8	4.2	4.0	2.5
62.0	137.470	27.638	105.246	37.125	533	526	23	11	8	611	369	5.1	.7	6.7	4.1	4.0	2.5
64.0	137.188	28.370	105.313	37.778	554	547	22	11	9	619	376	2.9	2.3	6.6	4.0	4.0	2.5
66.0	137.050	28.801	105.865	38.133	573	567	19	10	9	636	382	5.6	2.0	6.6	3.9	4.0	2.5
68.0	136.726	29.215	106.296	38.353	594	588	21	11	9	655	391	6.5	3.3	6.6	3.9	4.0	2.5
70.0	136.608	29.645	106.903	38.703	616	610	22	11	9	674	397	6.5	2.1	6.6	3.9	4.0	2.5

DAY,MONTH AND HOUR 15111442 FLIGHT 1 RUN 2

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
10.0	167.646	4.708	39.200	15.755	43	37	37	4	4	46	33	3.1	2.3	3.1	2.3	.9	.6
12.0	165.960	5.566	44.706	17.778	51	45	8	4	4	59	43	4.3	3.3	3.3	2.4	1.1	.8
14.0	164.591	6.518	48.673	19.693	59	53	8	4	4	68	52	3.3	2.9	3.3	2.5	1.2	.9
16.0	163.240	7.305	52.920	21.268	66	61	8	4	4	80	60	3.9	2.8	3.4	2.6	1.3	1.0
18.0	162.065	8.271	57.146	23.258	76	70	10	5	4	92	67	4.2	2.4	3.5	2.5	1.5	1.0
20.0	161.206	9.166	61.873	25.303	86	80	10	5	4	107	71	5.1	1.4	3.7	2.4	1.6	1.1
22.0	159.810	9.370	68.058	25.371	91	85	5	2	4	128	79	7.2	2.7	4.0	2.4	1.7	1.1
24.0	158.011	9.883	75.683	25.561	100	95	10	5	4	159	90	10.3	3.8	4.5	2.6	1.9	1.2
26.0	156.876	10.263	80.108	25.640	107	102	7	4	4	179	98	7.0	2.6	4.7	2.6	2.0	1.3
28.0	155.960	10.615	84.948	25.803	116	110	8	4	4	203	103	8.2	2.0	4.9	2.5	2.2	1.3
30.0	155.033	10.976	88.963	25.775	124	118	8	4	4	227	110	8.0	2.3	5.2	2.5	2.4	1.3
32.0	153.945	11.350	91.581	25.568	132	126	8	4	4	247	120	6.9	3.3	5.3	2.5	2.5	1.4
36.0	152.541	12.240	96.796	25.941	151	145	19	5	4	289	132	7.1	2.1	5.5	2.5	2.8	1.5
38.0	151.813	12.613	99.258	25.913	160	154	10	5	4	312	139	8.1	2.4	5.6	2.5	3.0	1.5
40.0	151.203	12.988	101.158	25.946	170	164	9	5	4	333	145	7.1	2.1	5.7	2.5	3.1	1.6
46.0	149.593	13.620	106.511	25.363	195	189	25	4	4	403	163	7.9	2.1	6.0	2.4	3.5	1.7
48.0	149.085	13.888	107.793	25.278	204	198	9	5	4	425	170	7.5	2.2	6.0	2.4	3.7	1.7
50.0	148.528	14.175	108.898	25.221	214	208	10	[illegible]	4	447	178	7.7	2.6	6.1	2.4	3.8	1.8
52.0	147.618	14.695	110.905	25.161	234	227	20	10	4	491	191	15.0	4.6	6.4	2.5	4.3	1.9
56.0	147.256	14.931	111.890	25.138	243	237	10	2	4	514	197	3.8	1.0	6.3	2.4	4.4	2.0
58.0	146.771	15.203	112.660	25.115	254	248	11	5	4	537	205	8.0	2.8	6.3	2.4	4.5	2.0
60.0	146.338	15.498	113.280	25.186	265	259	11	5	4	558	213	7.2	2.6	6.3	2.4	4.6	2.0
62.0	146.043	15.766	113.930	25.305	276	269	10	5	4	578	218	6.7	1.9	6.4	2.4	4.7	2.1
64.0	145.688	16.058	114.541	25.391	287	281	12	6	4	599	225	7.3	2.3	6.4	2.4	4.7	2.1
66.0	145.235	16.303	114.945	25.390	298	292	11	5	4	620	234	7.2	3.0	6.4	2.4	4.8	2.1
68.0	144.943	16.525	115.565	25.423	309	303	11	5	4	643	240	7.7	2.2	6.4	2.4	4.8	2.1
70.0	144.506	16.708	115.776	25.450	319	312	9	5	4	661	249	6.4	3.1	6.4	2.4	4.8	2.1
72.0	143.980	16.928	115.983	25.378	330	323	11	6	4	684	260	7.6	3.8	6.5	2.5	4.9	2.1
74.0	143.681	17.066	116.433	25.300	339	333	10	5	5	706	268	7.6	2.5	6.5	2.5	4.9	2.1
76.0	143.183	17.236	116.860	25.170	352	346	13	7	5	736	280	10.3	4.1	6.6	2.5	4.9	2.1

DAY,MONTH AND HOUR 15111444 FLIGHT 1 RUN 3

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	173.970	1.216	19.850	6.416	15	9	9	5	5	13	-5	4.3	-1.8	4.3	-1.8	.4	-.1
4.0	174.026	2.616	21.756	11.925	26	20	11	6	5	22	-10	3.1	-1.7	3.7	-1.7	.7	-.3
6.0	173.350	4.266	26.128	18.363	39	34	13	7	6	32	-9	3.6	.3	3.7	-1.1	1.1	-.3
8.0	172.770	5.611	31.950	25.233	52	46	12	6	6	47	-11	4.8	-.5	4.0	-.9	1.4	-.3
10.0	172.193	7.183	37.406	31.758	66	60	14	7	6	58	-11	3.8	.0	3.9	-.7	1.7	-.3
12.0	171.875	9.450	45.571	42.053	88	82	22	11	7	74	-15	5.6	-1.5	4.2	-.9	2.0	-.4
14.0	171.145	10.998	51.085	46.141	103	97	15	8	7	83	-12	3.1	1.0	4.1	-.6	2.1	-.3
16.0	170.851	12.245	56.125	50.008	116	110	13	7	7	92	-13	3.0	-.3	3.9	-.6	2.2	-.4
18.0	170.368	13.600	60.321	52.763	130	124	14	7	7	99	-11	2.4	.6	3.8	-.4	2.3	-.3
20.0	169.356	15.106	64.015	53.808	145	140	15	8	7	106	-4	2.4	2.4	3.6	-.1	2.4	-.3
22.0	167.466	16.950	71.598	54.058	167	161	22	11	7	124	8	5.9	4.1	3.8	.2	2.6	-.1
24.0	166.050	18.471	74.176	54.053	185	178	17	9	7	132	19	3.0	3.7	3.8	.5	2.7	-.0
26.0	165.296	20.016	79.778	55.466	205	200	21	11	8	147	21	5.2	.9	3.9	.6	2.9	.0
28.0	164.681	21.100	84.708	56.220	223	217	17	8	8	162	23	4.9	.6	3.9	.6	3.1	.0
30.0	163.495	21.975	91.100	55.491	241	235	18	9	8	185	29	8.0	1.9	4.2	.7	3.4	.1
32.0	162.158	22.848	93.790	54.551	257	251	16	8	8	202	39	5.7	3.4	4.3	.8	3.5	.1
34.0	161.096	23.016	97.525	53.001	266	261	10	5	8	223	45	7.1	2.2	4.5	.9	3.6	.2
36.0	159.736	23.333	99.498	51.900	282	272	11	5	8	242	56	6.4	3.8	4.6	1.1	3.6	.2
38.0	158.670	23.408	102.858	49.816	289	283	11	6	7	267	63	8.7	2.5	4.8	1.1	3.7	.2
40.0	157.415	23.488	104.463	48.168	298	293	9	5	7	288	74	7.3	3.8	4.9	1.3	3.8	.2
42.0	156.033	23.680	107.801	46.333	317	311	18	9	7	326	86	12.7	3.8	5.3	1.4	3.8	.3
44.0	154.608	23.863	109.703	44.670	333	327	17	8	7	359	100	11.5	4.8	5.6	1.5	3.9	.3
46.0	153.960	24.008	111.445	43.846	346	340	13	7	7	384	106	8.5	2.0	5.7	1.6	3.9	.3
48.0	153.168	24.288	112.828	43.108	362	357	16	8	7	411	114	9.1	2.8	5.8	1.6	3.9	.3
50.0	152.265	24.291	113.516	42.113	373	367	10	5	7	435	125	8.1	3.7	5.9	1.7	3.9	.3
52.0	151.691	24.366	114.296	41.483	383	377	10	5	7	455	131	6.9	2.4	6.0	1.7	3.9	.3
54.0	150.773	24.650	115.310	40.791	403	397	20	10	7	488	143	11.1	4.1	6.2	1.8	3.9	.3
56.0	150.670	24.825	116.673	40.575	416	410	13	7	7	510	144	7.6	.2	6.2	1.8	3.9	.3
60.0	150.153	25.120	118.840	39.903	444	439	28	7	7	559	150	8.3	1.1	6.3	1.7	3.9	.3

DAY,MONTH AND HOUR 15111446 FLIGHT 1 RUN 4

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	173.475	.571	19.371	4.085	10	4	4	2	2	5	2	1.7	.8	1.7	.8	.0	.0
6.0	171.481	3.476	23.686	11.533	31	25	21	5	4	8	17	.5	2.5	.9	1.9	.1	.4
8.0	168.646	5.610	29.343	15.628	47	41	16	8	5	15	37	2.2	6.7	1.2	3.1	.3	1.0
10.0	166.478	7.683	33.441	19.355	62	56	15	8	6	21	51	2.2	4.9	1.4	3.5	.5	1.4
12.0	164.491	9.458	36.890	22.116	76	70	14	7	6	27	64	2.1	4.5	1.6	3.7	.6	1.6
14.0	162.583	11.065	41.095	24.683	90	84	14	7	6	38	76	3.7	4.0	1.9	3.7	.7	1.8
16.0	160.208	13.041	44.866	26.616	104	100	17	8	6	48	92	3.2	5.5	2.0	3.9	.9	2.0
18.0	158.361	14.178	48.211	28.236	117	111	11	6	6	58	105	3.5	4.2	2.2	4.0	1.0	2.1
20.0	156.673	15.336	50.668	29.341	129	122	11	6	6	66	117	2.7	4.1	2.2	4.0	1.0	2.2
22.0	154.433	16.383	53.978	30.041	141	134	12	6	6	78	133	4.1	5.5	2.4	4.1	1.1	2.3
24.0	153.041	17.555	55.906	31.033	153	147	12	6	6	85	143	2.7	3.6	2.4	4.1	1.2	2.4
26.0	151.446	18.911	57.666	32.146	167	161	14	7	6	93	156	2.6	4.3	2.4	4.1	1.3	2.6
28.0	149.518	20.471	58.846	33.088	183	177	16	8	6	99	171	1.9	5.3	2.4	4.2	1.3	2.7
30.0	147.425	22.200	59.636	33.980	202	196	18	9	7	103	189	1.5	5.9	2.3	4.3	1.4	2.9
32.0	146.130	22.816	60.786	35.413	221	204	9	4	6	110	200	2.2	3.8	2.3	4.3	1.4	3.0
34.0	143.575	26.205	61.623	36.795	249	243	38	19	7	115	222	2.0	7.6	2.3	4.5	1.5	3.4
36.0	142.501	27.663	62.950	38.116	270	263	21	10	7	124	232	2.9	3.5	2.3	4.4	1.6	3.4
38.0	141.351	29.201	64.018	39.453	292	286	22	11	8	132	243	2.6	3.8	2.4	4.4	1.6	3.5
40.0	140.478	30.643	65.271	40.785	315	309	23	12	8	141	252	3.1	3.1	2.4	4.3	1.6	3.5
42.0	139.456	32.056	66.148	41.908	338	332	23	11	8	148	263	2.4	3.6	2.4	4.3	1.7	3.6
44.0	138.221	33.975	67.320	43.500	371	365	33	17	8	158	276	3.4	4.5	2.4	4.3	1.7	3.6
46.0	136.728	35.521	68.426	44.530	403	397	31	16	9	168	293	3.6	5.6	2.5	4.3	1.7	3.6
48.0	135.533	36.633	68.790	45.145	425	419	22	11	9	173	306	1.7	4.4	2.5	4.3	1.7	3.6
50.0	134.135	38.300	69.295	46.216	459	453	34	17	9	180	322	2.4	5.4	2.5	4.4	1.7	3.6
52.0	133.046	38.896	70.410	46.488	481	475	22	11	9	192	336	4.1	4.9	2.5	4.4	1.7	3.6
54.0	132.470	39.400	71.536	46.933	501	495	20	10	9	204	346	3.9	3.2	2.6	4.4	1.7	3.6
56.0	131.171	40.198	72.410	47.275	529	523	28	14	9	216	364	4.1	6.1	2.6	4.4	1.7	3.6
58.0	130.441	40.778	73.061	47.650	550	544	21	10	9	224	375	3.0	3.8	2.6	4.4	1.7	3.6
60.0	129.703	41.128	74.231	47.845	573	566	22	11	9	239	388	4.9	4.6	2.7	4.4	1.7	3.6

DAY,MONTH AND HOUR 15111448 FLIGHT 1 RUN 5

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	172.186	1.296	22.691	5.988	16	10	10	5	5	9	11	3.1	3.7	3.1	3.7	.3	.4
6.0	165.673	5.211	40.801	15.300	46	40	31	8	7	45	50	6.2	6.6	5.2	5.6	1.4	1.5
8.0	162.475	7.195	50.035	19.466	64	58	18	9	7	70	69	8.3	6.6	6.0	5.9	2.2	2.1
10.0	160.095	8.528	53.886	21.133	76	70	12	6	7	81	86	3.7	5.9	5.5	5.9	2.3	2.4
12.0	157.998	9.716	58.286	22.668	88	82	12	6	7	96	101	5.2	5.0	5.4	5.7	2.5	2.5
14.0	154.711	11.573	64.648	24.641	109	103	21	10	7	122	125	9.0	8.4	5.9	6.1	2.9	3.0
16.0	152.698	12.428	68.378	25.175	120	114	12	6	7	141	142	6.3	5.5	6.0	6.0	3.1	3.1
18.0	150.870	13.236	71.660	25.666	132	126	12	6	7	160	157	6.4	5.3	6.0	6.0	3.3	3.3
20.0	149.063	13.711	74.866	25.575	142	136	10	5	7	181	174	7.2	5.7	6.2	5.9	3.4	3.4
22.0	147.391	14.425	77.281	25.850	154	148	12	6	7	200	190	6.5	5.6	6.2	5.9	3.6	3.5
24.0	145.508	14.921	79.318	25.650	165	159	11	5	7	219	210	6.8	6.8	6.2	6.0	3.8	3.7
26.0	144.045	15.371	81.530	25.801	178	170	11	6	7	241	227	7.4	5.7	6.3	6.0	4.0	3.8
28.0	142.693	15.791	83.236	25.605	187	181	11	5	6	261	244	6.8	5.6	6.4	5.9	4.1	4.0
30.0	142.413	16.158	84.905	25.501	191	190	9	4	6	276	248	5.1	1.6	6.3	5.6	4.2	4.0
32.0	140.258	16.463	86.258	25.430	209	202	12	6	6	302	277	8.8	9.7	6.4	5.9	4.4	4.2
34.0	139.330	16.793	87.735	25.466	220	214	11	6	6	323	291	7.2	5.0	6.5	5.8	4.6	4.3
36.0	138.035	17.065	88.713	25.233	231	225	11	6	6	344	311	7.1	6.8	6.5	5.9	4.7	4.5
38.0	137.178	17.255	89.945	25.113	241	235	10	5	6	366	327	7.5	5.3	6.6	5.9	4.9	4.6
40.0	136.461	17.418	91.166	25.025	251	245	10	5	6	388	341	7.6	4.9	6.6	5.8	5.0	4.6
42.0	135.006	17.590	92.151	24.650	265	259	14	7	6	418	368	10.1	9.3	6.8	6.0	5.1	4.8
44.0	134.053	17.683	92.863	24.391	275	268	10	5	6	440	388	7.6	6.7	6.8	6.0	5.2	4.9
46.0	132.576	17.900	93.440	24.108	290	283	15	8	6	469	419	9.9	10.5	7.0	6.2	5.3	5.0
48.0	131.853	18.121	93.858	24.105	300	294	11	5	6	487	435	6.1	5.7	6.9	6.2	5.4	5.0
58.0	128.033	19.241	95.025	23.215	344	354	60	6	6	577	532	6.1	6.6	6.8	6.3	5.4	5.1
60.0	127.428	18.403	95.203	23.041	352	345	-9	-5	6	593	550	5.6	6.0	6.7	6.2	5.4	5.1
62.0	126.768	18.350	95.393	22.758	358	352	7	4	6	612	570	6.4	6.9	6.7	6.3	5.4	5.1
64.0	126.121	18.358	95.445	22.591	366	359	7	4	6	628	589	5.3	6.6	6.7	6.3	5.4	5.1

DAY,MONTH AND HOUR 15111452 FLIGHT 1 RUN 7

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	172.420	1.943	22.953	8.081	20	14	14	7	7	12	8	4.2	2.6	4.2	2.6	.7	.4
4.0	171.580	3.491	25.253	12.350	32	26	12	6	7	16	13	1.2	1.8	2.7	2.2	.8	.6
6.0	170.260	4.616	28.615	15.300	41	35	9	4	6	21	22	1.7	2.9	2.4	2.4	.9	.8
8.0	168.213	6.168	33.965	18.388	53	47	12	6	6	31	34	3.3	4.3	2.6	2.9	1.1	1.1
10.0	165.756	7.545	41.485	21.436	65	59	12	6	6	48	48	5.9	4.8	3.3	3.3	1.5	1.4
12.0	162.890	8.908	48.435	23.303	77	72	13	6	6	65	67	5.8	6.3	3.7	3.8	1.8	1.7
14.0	160.500	9.751	53.276	23.901	86	80	9	4	6	79	83	4.7	5.6	3.8	4.1	1.9	1.8
16.0	157.690	11.600	59.546	26.296	105	99	19	10	6	101	103	7.4	6.7	4.3	4.4	2.2	2.1
18.0	154.830	13.638	65.576	28.600	129	123	23	12	7	126	124	8.6	7.3	4.8	4.7	2.6	2.4
20.0	151.288	15.031	71.056	28.811	149	143	20	10	7	156	154	10.2	10.1	5.3	5.2	3.2	3.0
22.0	147.998	15.991	74.900	28.421	166	160	17	9	7	184	184	9.6	10.5	5.7	5.7	3.5	3.3
24.0	146.091	16.416	77.033	28.046	177	171	10	5	7	203	204	6.4	6.6	5.8	5.8	3.6	3.4
26.0	143.980	16.808	78.713	27.500	187	181	10	5	7	222	226	6.4	7.8	5.8	5.9	3.8	3.6
28.0	142.676	17.020	80.670	27.198	196	190	9	4	7	241	242	6.7	5.3	5.9	5.9	3.9	3.7
30.0	141.120	17.258	82.080	26.788	205	199	9	5	7	260	261	6.4	6.6	5.9	5.9	4.0	3.8
32.0	140.040	17.286	83.253	26.341	211	205	6	3	6	276	276	5.4	4.9	5.9	5.9	4.1	3.9
34.0	139.248	17.170	84.890	25.895	216	210	5	3	6	296	288	6.8	4.2	5.9	5.8	4.1	3.9
36.0	138.200	16.945	85.940	25.113	219	213	3	2	6	313	304	6.0	5.4	5.9	5.8	4.2	4.0
38.0	137.313	16.785	87.235	24.571	224	218	5	2	6	334	319	7.0	5.1	6.0	5.7	4.2	4.0
40.0	136.176	16.708	88.105	24.003	230	224	6	3	6	353	338	6.6	6.4	6.0	5.8	4.3	4.1
42.0	135.330	16.666	88.813	23.616	235	229	5	3	5	369	353	5.6	5.1	6.0	5.7	4.4	4.1
44.0	135.701	16.600	89.688	23.300	232	230	1	1	5	377	349	2.6	-1.2	5.8	5.4	4.4	4.1
46.0	133.821	16.646	90.010	23.033	246	240	10	5	5	401	381	8.0	11.0	5.9	5.7	4.5	4.3
50.0	132.241	17.118	91.386	23.051	267	261	22	5	5	439	415	6.6	5.8	6.0	5.7	4.6	4.4
54.0	131.220	17.878	92.385	23.660	292	285	24	6	5	470	440	5.2	4.3	5.9	5.6	4.7	4.5
56.0	130.986	18.375	93.063	24.163	306	300	14	7	5	485	449	5.3	2.9	5.9	5.5	4.8	4.5
58.0	130.371	18.836	93.348	24.533	321	314	14	7	5	500	464	5.0	5.1	5.9	5.5	4.8	4.6
60.0	130.135	19.291	93.911	24.958	334	328	14	7	5	515	473	5.1	3.0	5.9	5.4	4.8	4.6
62.0	129.901	19.683	94.565	25.351	349	342	14	7	6	532	483	5.9	3.3	5.9	5.3	4.8	4.6
64.0	129.893	20.175	95.410	25.883	365	359	16	8	6	551	489	6.3	2.1	5.9	5.2	4.9	4.6

DAY.MONTH AND HOUR 15111454 FLIGHT 1 RUN 8

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	170.486	2.233	28.218	8.620	23	17	17	8	8	21	20	7.0	6.7	7.0	6.7	1.4	1.3
4.0	169.501	3.883	31.290	13.141	35	29	13	6	7	27	25	2.1	1.9	4.6	4.3	1.6	1.5
6.0	168.070	5.533	40.010	18.811	50	44	15	7	7	50	28	7.9	1.1	5.7	3.2	2.2	1.6
8.0	166.115	6.736	48.313	22.075	61	55	11	6	7	70	38	6.7	3.4	5.9	3.3	2.6	1.8
10.0	165.005	7.791	53.281	24.820	71	66	10	5	7	82	44	4.3	1.9	5.6	3.0	2.8	1.9
14.0	162.226	9.550	63.748	27.866	91	85	19	5	6	112	60	5.1	2.8	5.5	2.9	3.0	2.0
16.0	161.111	10.440	67.665	29.175	100	95	10	5	6	125	67	4.4	2.4	5.3	2.9	3.1	2.1
18.0	159.745	11.100	71.731	29.633	109	103	9	4	6	141	77	5.2	3.2	5.3	2.9	3.3	2.1
20.0	158.328	11.791	75.388	29.928	119	113	10	5	6	157	87	5.5	3.5	5.3	3.0	3.4	2.2
22.0	156.770	12.516	78.241	29.991	129	123	10	5	6	172	100	5.3	4.3	5.3	3.1	3.5	2.3
24.0	155.308	13.275	81.133	30.208	140	134	11	6	6	189	112	5.9	4.1	5.4	3.2	3.6	2.4
26.0	154.403	14.046	83.928	30.921	152	147	12	6	6	206	119	5.6	2.5	5.4	3.1	3.8	2.5
28.0	153.581	14.733	86.955	31.495	165	159	12	6	6	225	126	6.5	2.3	5.5	3.1	4.0	2.5
30.0	152.560	15.380	89.200	31.700	177	171	12	6	6	243	135	6.1	3.2	5.5	3.1	4.1	2.6
32.0	151.805	16.075	91.075	32.183	189	183	13	6	6	259	142	5.4	2.5	5.5	3.0	4.3	2.7
34.0	150.698	16.685	92.800	32.233	202	196	13	6	6	278	154	6.4	3.9	5.6	3.1	4.4	2.8
36.0	149.470	17.700	94.918	32.780	223	217	20	10	6	302	167	8.5	4.6	5.7	3.2	4.8	3.0
38.0	148.698	18.198	96.568	32.828	236	230	13	6	6	322	176	6.8	3.1	5.8	3.2	4.9	3.0
40.0	147.695	18.771	97.125	32.908	249	242	13	6	6	337	189	5.0	4.2	5.7	3.2	5.0	3.1
42.0	146.375	19.450	98.340	32.845	267	261	18	9	6	362	206	8.6	5.9	5.9	3.3	5.2	3.2
44.0	145.243	19.816	98.683	32.558	278	272	11	6	6	378	221	5.6	5.3	5.9	3.4	5.2	3.3
46.0	144.151	20.001	98.871	32.105	287	281	9	4	6	394	237	5.2	5.3	5.8	3.5	5.3	3.3
48.0	143.176	20.191	99.206	31.728	296	290	9	5	6	410	251	5.5	5.0	5.8	3.6	5.3	3.3
50.0	142.341	20.358	99.530	31.453	305	299	9	4	6	425	264	5.2	4.5	5.8	3.6	5.3	3.4
54.0	140.368	20.650	99.800	30.688	323	317	18	5	6	457	297	5.4	5.5	5.8	3.7	5.4	3.4
56.0	138.980	20.761	100.143	30.086	337	330	13	7	6	484	322	9.2	8.5	5.9	3.9	5.4	3.4
58.0	138.083	20.850	100.315	29.738	346	340	9	5	6	502	339	6.0	5.8	5.9	4.0	5.4	3.4
60.0	137.233	20.971	100.435	29.448	355	349	10	5	6	519	356	5.8	5.7	5.9	4.0	5.4	3.5
62.0	136.533	21.046	100.948	29.188	367	360	11	6	6	541	372	7.7	5.5	5.9	4.1	5.4	3.5
64.0	135.773	21.241	101.038	29.083	378	372	11	6	6	558	388	5.7	5.6	5.9	4.1	5.4	3.5

DAY,MONTH AND HOUR 15111658 FLIGHT 1 RUN 9

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT=WSX MPH	SWT=WSY MPH
2.0	172.978	1.188	22.791	6.191	15	9	9	4	4	16	1	5.6	.4	5.6	.4	.6	.0
4.0	171.930	2.870	27.245	12.266	29	22	13	7	6	26	6	3.3	1.5	4.5	.9	.9	.1
6.0	171.185	4.586	32.023	17.883	42	36	14	7	6	38	7	4.1	.4	4.3	.8	1.4	.2
8.0	171.053	5.966	36.910	24.441	55	49	12	6	6	52	2	4.7	-1.6	4.4	.2	1.7	.1
10.0	170.466	7.816	43.058	31.716	72	65	17	8	7	65	2	4.6	-.1	4.4	.1	1.9	.1
12.0	169.086	9.666	50.688	36.741	89	83	18	9	7	80	8	5.0	2.3	4.5	.5	2.2	.2
14.0	168.300	11.291	55.320	40.583	105	99	16	8	7	89	12	3.2	1.2	4.4	.6	2.3	.2
16.0	167.130	13.050	57.813	42.805	121	115	16	8	7	95	21	1.8	3.0	4.0	.9	2.4	.4
18.0	164.955	14.783	67.566	44.450	143	137	21	11	8	119	33	8.4	4.2	4.5	1.3	2.7	.5
24.0	160.175	18.431	88.481	45.358	201	195	58	10	8	195	61	8.7	3.2	5.6	1.7	3.7	.9
26.0	159.050	19.316	91.780	45.225	217	211	16	8	8	215	69	6.5	2.7	5.6	1.8	3.9	1.0
28.0	157.971	20.436	94.375	45.483	235	230	19	10	8	233	77	6.2	2.8	5.7	1.9	4.2	1.1
30.0	157.750	21.366	96.540	45.246	242	246	16	8	8	244	78	3.9	.2	5.6	1.8	4.2	1.1
32.0	155.460	22.016	98.153	44.583	270	264	18	9	8	271	100	9.3	7.5	5.8	2.1	4.4	1.2
34.0	154.358	22.558	99.451	44.066	284	278	14	7	8	289	111	6.0	3.7	5.8	2.2	4.5	1.3
36.0	153.170	23.236	100.071	43.713	299	293	15	8	8	305	123	5.3	4.3	5.8	2.3	4.5	1.3
38.0	152.316	23.476	101.950	42.986	312	306	13	6	8	327	132	7.7	2.9	5.9	2.4	4.6	1.3
40.0	150.196	24.016	102.775	41.675	333	328	21	11	8	358	157	10.7	8.5	6.1	2.7	4.6	1.4
42.0	148.675	24.220	103.175	40.588	347	341	13	7	8	381	176	7.8	6.6	6.2	2.9	4.7	1.4
44.0	146.851	24.488	102.805	39.558	361	355	14	7	8	402	201	7.0	8.4	6.2	3.1	4.7	1.4
46.0	144.545	24.833	102.710	38.335	382	376	21	11	8	434	234	10.9	11.4	6.4	3.5	4.7	1.4
48.0	143.035	25.028	102.646	37.591	397	390	15	7	8	456	257	7.6	8.0	6.5	3.7	4.7	1.4
50.0	141.846	25.461	102.306	37.633	413	406	15	8	8	470	276	4.8	6.5	6.4	3.8	4.7	1.4
54.0	139.713	26.128	101.616	37.316	443	432	27	7	8	495	312	4.3	6.1	6.3	3.9	4.7	1.4
56.0	138.840	26.378	101.600	36.825	452	446	13	7	8	510	328	5.1	5.5	6.2	4.0	4.7	1.4
58.0	138.018	26.671	101.594	36.716	466	460	14	7	8	525	344	5.1	5.4	6.2	4.0	4.7	1.4
60.0	137.195	26.998	101.300	36.695	479	473	13	6	8	535	359	3.4	5.2	6.1	4.1	4.7	1.4
62.0	136.280	27.200	101.036	36.466	491	485	12	6	8	548	377	4.2	6.1	6.0	4.1	4.7	1.4
64.0	135.436	27.421	100.575	35.350	483	495	10	5	8	555	393	2.5	5.4	5.9	4.2	4.7	1.4
66.0	134.331	27.466	100.135	35.920	512	505	10	5	8	568	415	4.4	7.5	5.9	4.3	4.7	1.4

SUM WS(X)= 4.7 SUM WS(Y)= 1.5

DAY,MONTH AND HOUR 15111700 FLIGHT 1 RUN 10

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	173.078	1.441	21.203	6.746	17	11	11	5	5	10	3	3.4	1.1	3.4	1.1	.4	.1
4.0	171.016	4.733	24.035	11.783	33	34	24	12	9	6	22	-1.3	6.2	1.1	3.7	.1	1.3
6.0	169.711	6.000	27.058	16.241	48	44	9	5	7	11	30	1.6	2.8	1.3	3.4	.2	1.4
8.0	168.411	7.166	31.811	19.238	57	54	10	5	7	23	35	4.2	1.9	2.0	3.0	.5	1.5
10.0	166.710	8.436	35.090	21.691	68	63	10	5	6	29	47	1.8	4.0	1.9	3.2	.5	1.7
12.0	165.025	9.883	38.826	23.800	78	75	12	6	6	37	58	2.7	3.6	2.1	3.3	.6	1.8
14.0	163.658	11.650	42.166	26.436	91	90	15	7	6	45	66	2.9	2.8	2.2	3.2	.7	1.9
16.0	162.373	13.216	45.700	29.183	108	104	14	7	7	55	74	3.4	2.6	2.3	3.1	.9	2.0
18.0	161.216	14.716	49.166	31.741	119	119	15	7	7	65	80	3.6	2.3	2.5	3.0	1.0	2.1
20.0	159.426	16.413	51.641	33.933	138	135	16	8	7	72	93	2.3	4.5	2.5	3.2	1.1	2.2
22.0	158.118	17.816	53.930	35.206	151	149	14	7	7	80	103	2.6	3.2	2.5	3.2	1.1	2.3
24.0	156.731	18.941	58.136	37.275	169	164	15	7	7	95	112	5.3	3.1	2.7	3.2	1.3	2.4
26.0	154.823	20.008	61.216	38.246	186	177	14	7	7	108	126	4.3	4.9	2.8	3.3	1.4	2.6
30.0	153.270	20.625	64.430	38.563	199	188	11	3	6	123	138	2.5	2.0	2.8	3.1	1.5	2.6
32.0	151.891	21.418	69.045	38.853	212	205	16	8	6	145	149	7.7	3.6	3.1	3.2	1.7	2.7
34.0	150.398	22.263	72.256	39.150	228	221	16	8	7	164	162	6.3	4.4	3.3	3.2	1.9	2.9
36.0	148.871	23.091	74.710	39.018	242	237	16	8	7	180	176	5.7	4.8	3.4	3.3	2.1	3.0
38.0	147.313	24.260	76.641	39.431	261	258	21	10	7	196	191	5.4	5.2	3.5	3.4	2.2	3.1
40.0	146.005	24.961	80.068	40.078	266	279	21	10	7	222	205	8.9	4.8	3.8	3.5	2.4	3.2
42.0	144.945	25.763	81.225	40.018	299	295	17	8	7	235	217	4.3	4.0	3.8	3.5	2.4	3.3
44.0	143.728	26.500	82.258	40.366	318	312	17	8	7	248	231	4.5	4.8	3.8	3.6	2.5	3.3
46.0	141.788	27.778	83.290	40.493	344	341	28	14	7	266	254	6.3	8.0	3.9	3.8	2.5	3.3
48.0	140.558	28.475	83.725	40.758	363	357	17	8	7	277	270	3.7	5.3	3.9	3.8	2.5	3.3
50.0	139.451	29.253	84.258	40.825	380	377	19	10	8	289	285	3.9	5.0	3.9	3.9	2.5	3.3
52.0	138.533	30.011	84.488	41.066	396	394	16	9	8	297	297	2.7	4.2	3.9	3.9	2.5	3.3
54.0	137.165	30.650	84.593	41.353	418	412	16	9	8	307	315	3.5	6.3	3.9	4.0	2.5	3.3
56.0	136.243	31.418	84.643	41.383	432	431	18	9	8	314	328	2.3	4.4	3.8	4.0	2.5	3.3
58.0	135.003	31.900	84.595	41.736	454	446	16	8	8	322	346	2.8	6.0	3.8	4.1	2.5	3.3
60.0	133.406	32.775	84.796	41.646	478	474	26	14	8	336	370	4.9	8.3	3.8	4.2	2.5	3.3
62.0	133.178	33.026	85.131	41.950	489	483	9	5	8	342	375	2.0	1.6	3.8	4.1	2.5	3.3

SUM WS(X)= 2.6 SUM WS(Y)= 3.4

DAY,MONTH AND HOUR 15111702 FLIGHT 1 RUN 11

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	172.365	1.950	23.413	8.125	20	15	15	7	7	14	7	4.7	2.5	4.7	2.5	.8	.4
4.0	170.731	2.908	27.478	10.466	29	22	7	4	5	19	18	1.8	3.8	3.3	3.1	.9	.6
6.0	168.065	5.066	33.385	15.208	44	38	16	8	6	28	36	2.9	6.2	3.2	4.1	1.3	1.4
10.0	166.988	6.283	35.040	17.536	53	47	9	2	5	29	44	.3	1.4	2.0	3.0	1.3	1.5
12.0	165.521	7.808	38.281	20.500	65	59	12	6	5	36	54	2.3	3.2	2.1	3.1	1.4	1.7
14.0	164.455	9.300	40.686	23.308	77	71	12	6	5	42	61	1.9	2.3	2.0	2.9	1.5	1.8
16.0	162.648	10.758	44.491	25.541	90	84	13	6	5	51	72	3.2	4.0	2.2	3.1	1.6	1.9
18.0	161.398	12.200	47.041	27.753	102	96	13	6	5	58	81	2.3	2.8	2.2	3.1	1.7	2.0
20.0	159.695	13.575	49.846	29.300	115	109	12	6	5	66	93	2.7	4.1	2.2	3.2	1.8	2.1
22.0	158.668	15.083	51.456	31.288	128	122	14	7	6	71	100	1.7	2.5	2.2	3.1	1.8	2.2
24.0	156.296	17.166	54.545	32.983	148	143	20	10	6	81	117	3.5	6.0	2.3	3.3	2.0	2.5
26.0	154.641	18.383	56.938	34.055	162	156	13	7	6	90	130	3.2	4.2	2.4	3.4	2.1	2.6
28.0	153.006	19.736	58.510	34.983	177	170	14	7	6	97	143	2.3	4.4	2.4	3.5	2.2	2.8
30.0	151.758	20.850	61.125	36.083	191	185	15	7	6	109	152	4.1	3.2	2.5	3.5	2.3	2.9
32.0	150.478	22.050	61.828	36.750	204	198	13	7	6	113	163	1.3	3.7	2.4	3.5	2.3	3.0
34.0	148.783	23.061	63.788	37.016	218	213	15	7	6	124	177	3.7	4.9	2.5	3.6	2.4	3.1
36.0	147.843	23.816	65.390	37.875	232	225	12	6	6	133	185	3.1	2.8	2.5	3.5	2.5	3.2
38.0	146.221	24.778	67.090	38.100	246	240	16	8	6	144	200	3.8	5.1	2.6	3.6	2.6	3.3
40.0	145.251	25.520	69.148	38.725	261	255	15	7	6	157	210	4.5	3.2	2.7	3.6	2.6	3.3
42.0	143.890	26.816	71.433	39.533	284	279	24	12	7	175	227	6.0	5.8	2.8	3.7	2.8	3.5
44.0	142.743	27.846	73.105	40.041	301	299	20	10	7	188	236	4.4	3.2	2.9	3.7	2.9	3.5
46.0	141.726	28.045	74.768	40.225	314	310	11	5	7	202	248	4.9	4.0	3.0	3.7	2.9	3.5
48.0	140.386	28.858	76.450	40.558	337	331	21	10	7	219	264	5.7	5.5	3.1	3.7	2.9	3.6
50.0	139.631	29.351	77.685	40.800	352	346	15	7	7	231	274	4.3	3.4	3.2	3.7	2.9	3.6
52.0	138.455	30.050	77.960	40.958	367	361	15	8	7	239	288	2.4	4.8	3.1	3.8	2.9	3.6
54.0	137.348	30.383	79.016	40.816	382	375	15	7	7	253	303	4.8	5.1	3.2	3.8	2.9	3.6
56.0	136.745	30.826	80.245	41.091	398	391	16	8	7	267	313	4.8	3.3	3.2	3.8	2.9	3.6
58.0	135.805	31.385	80.768	41.250	414	408	16	8	7	277	326	3.4	4.5	3.3	3.8	2.9	3.6
60.0	135.075	31.766	81.843	41.380	431	425	17	8	7	292	338	5.1	4.2	3.3	3.8	2.9	3.6

SUM WS(X)= 3.0 SUM WS(Y)= 3.6

DAY,MONTH AND HOUR 15111704 FLIGHT 1 RUN 12

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT=WSX MPH	SWT=WSY MPH
2.0	173.095	1.653	19.916	6.916	16	12	12	6	6	4	6	1.3	2.1	1.3	2.1	.1	.2
4.0	172.081	2.690	22.998	9.783	26	20	8	4	5	10	12	2.0	1.9	1.7	2.0	.3	.4
6.0	170.728	4.153	26.790	13.650	37	31	11	6	5	16	20	2.3	2.7	1.9	2.2	.5	.7
8.0	169.003	5.600	31.406	16.983	48	42	11	6	5	25	30	2.9	3.6	2.1	2.6	.7	.9
10.0	167.[illegible]	6.946	35.308	19.566	58	53	11	5	5	32	42	2.3	3.9	2.1	2.8	.8	1.1
16.0	162.636	11.810	45.770	28.100	99	93	41	7	6	56	71	2.7	3.4	2.4	3.0	1.1	1.5
18.0	160.928	13.186	48.788	29.658	111	106	12	6	6	64	83	2.7	4.0	2.4	3.1	1.2	1.6
20.0	159.315	14.706	50.795	31.366	126	119	13	7	6	69	95	1.8	4.0	2.3	3.2	1.3	1.7
22.0	157.806	16.316	52.443	32.691	141	134	15	7	6	74	106	1.7	3.8	2.3	3.3	1.3	1.8
24.0	156.041	17.691	54.766	32.750	149	147	14	7	6	82	119	2.7	4.5	2.3	3.4	1.4	2.0
26.0	154.121	20.008	56.921	35.900	177	171	23	12	7	90	134	2.8	5.0	2.4	3.5	1.5	2.2
28.0	152.656	21.555	57.856	36.933	192	186	16	8	7	94	146	1.3	4.0	2.3	3.5	1.6	2.3
30.0	151.216	22.816	59.665	37.866	208	202	15	8	7	102	157	2.9	3.9	2.3	3.6	1.7	2.5
32.0	149.621	24.306	60.486	38.623	224	218	17	8	7	107	170	1.5	4.5	2.3	3.6	1.7	2.6
34.0	148.396	25.433	62.385	39.516	240	234	16	8	7	117	181	3.4	3.5	2.3	3.6	1.8	2.7
36.0	146.958	26.601	63.730	40.075	256	251	17	8	7	125	193	2.8	4.3	2.4	3.7	1.9	2.8
38.0	145.855	27.500	65.206	40.746	272	266	15	7	7	134	203	3.1	3.4	2.4	3.6	1.9	2.8
40.0	144.381	28.588	65.763	40.075	277	281	16	8	7	139	217	1.7	4.6	2.4	3.7	1.9	2.9
42.0	142.448	29.680	67.923	41.583	311	304	23	11	7	155	236	5.4	6.5	2.5	3.8	2.0	2.9
44.0	142.000	30.038	68.723	41.670	318	312	8	4	7	161	241	2.0	1.6	2.5	3.7	2.0	2.9
46.0	140.511	30.810	70.121	42.045	339	330	18	9	7	173	256	4.2	5.4	2.6	3.8	2.0	3.0
48.0	138.830	31.800	71.315	42.216	359	353	22	11	7	185	275	4.2	6.3	2.6	3.9	2.0	3.0
50.0	137.748	32.341	71.961	42.550	374	366	14	7	7	193	287	2.6	4.2	2.6	3.9	2.0	3.0
52.0	136.890	32.983	72.398	42.468	385	380	14	7	7	199	297	2.0	3.4	2.6	3.9	2.0	3.0
54.0	135.530	33.525	72.893	42.783	405	396	15	8	7	207	313	2.7	5.5	2.6	4.0	2.0	3.0
56.0	134.656	34.161	73.508	42.836	418	412	17	8	7	215	325	2.7	3.8	2.6	4.0	2.0	3.0
58.0	133.623	34.583	75.115	43.016	440	434	21	11	7	233	341	6.2	5.5	2.7	4.0	2.0	3.0
60.0	132.661	34.988	75.796	43.091	456	450	16	8	7	243	354	3.5	4.7	2.8	4.0	2.0	3.0

SUM WS(X)= 2.1 SUM WS(Y)= 3.0

DAY,MONTH AND HOUR 15111706 FLIGHT 1 RUN 13

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	Dh FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT-WSX MPH	SWT-WSY MPH
2.0	172.945	1.315	21.568	6.206	16	10	10	5	5	11	4	3.6	1.4	3.6	1.4	.4	.1
4.0	172.125	3.243	23.940	11.783	3[illegible]	24	14	7	6	14	9	1.3	1.7	2.4	1.6	.5	.3
6.0	171.503	4.245	26.668	15.008	3[illegible]	32	8	4	5	21	11	2.3	.7	2.4	1.3	.7	.4
8.0	169.305	6.066	35.170	20.293	53	47	15	8	6	39	22	6.2	3.6	3.4	1.9	1.2	.7
10.0	167.450	7.351	40.663	23.145	64	58	11	5	6	50	33	3.7	3.8	3.4	2.3	1.4	.9
12.0	165.870	8.375	45.433	24.983	73	68	9	5	6	61	43	3.6	3.4	3.5	2.5	1.5	1.0
14.0	164.285	9.291	49.206	26.196	82	76	8	4	5	70	54	3.0	3.6	3.4	2.6	1.6	1.1
16.0	162.396	10.096	52.558	26.533	89	83	8	4	5	78	67	2.9	4.6	3.3	2.9	1.7	1.2
18.0	159.715	11.233	58.296	27.330	101	96	12	6	5	96	86	6.1	6.4	3.6	3.3	1.9	1.4
20.0	158.350	12.083	62.211	28.425	111	106	10	5	5	110	95	4.8	3.1	3.7	3.3	2.0	1.5
22.0	157.480	13.166	64.533	30.083	123	117	12	6	5	119	101	3.1	2.1	3.7	3.1	2.1	1.5
24.0	155.983	14.131	66.560	30.696	134	128	11	5	5	128	113	3.2	4.1	3.6	3.2	2.1	1.6
26.0	154.140	15.286	67.070	31.031	146	140	12	6	5	133	129	1.5	5.5	3.5	3.4	2.2	1.7
28.0	152.741	16.266	68.298	31.608	157	151	11	6	5	140	141	2.5	4.1	3.4	3.4	2.2	1.9
30.0	150.976	17.246	69.160	31.800	169	163	12	6	5	147	157	2.4	5.3	3.3	3.6	2.3	2.0
32.0	149.688	18.178	70.255	32.346	180	174	12	6	5	155	169	2.7	3.9	3.3	3.6	2.4	2.1
34.0	148.426	19.150	70.608	32.841	192	186	11	6	5	159	180	1.5	4.0	3.2	3.6	2.4	2.2
36.0	146.280	20.418	71.703	33.250	210	203	18	9	6	170	201	3.7	7.0	3.2	3.8	2.5	2.4
38.0	144.771	21.215	71.940	33.316	220	214	11	5	6	175	215	1.7	5.0	3.1	3.9	2.6	2.5
40.0	142.848	22.400	72.356	33.708	237	231	17	8	6	183	235	2.5	6.6	3.1	4.0	2.6	2.7
42.0	141.675	23.053	73.240	33.985	249	243	12	6	6	192	247	3.1	4.3	3.1	4.0	2.7	2.8
44.0	140.438	23.575	73.708	33.966	259	253	10	5	6	198	261	2.3	4.6	3.1	4.0	2.7	2.8
46.0	138.950	23.946	74.600	33.691	270	264	11	5	6	210	278	3.8	5.8	3.1	4.1	2.7	2.9
48.0	137.815	24.413	75.170	33.743	280	274	11	5	6	218	291	2.8	4.6	3.1	4.1	2.8	2.9
50.0	135.295	24.931	76.980	33.216	300	295	21	11	6	243	324	8.6	11.3	3.3	4.4	2.9	3.1
52.0	133.581	25.265	76.325	32.843	309	303	7	4	6	244	344	.3	6.8	3.2	4.5	2.9	3.1
54.0	131.576	25.491	76.253	32.316	319	313	10	5	6	252	370	2.6	8.8	3.2	4.7	2.9	3.2
56.0	130.363	25.658	76.520	32.026	324	321	9	4	6	260	387	2.8	5.9	3.2	4.7	2.9	3.2
58.0	128.785	25.975	76.643	31.770	339	333	12	6	6	269	410	3.0	7.7	3.2	4.8	2.9	3.2
60.0	127.138	26.300	76.495	31.525	351	345	12	6	6	275	433	2.1	8.0	3.1	4.9	2.9	3.2

SUM WS(X)= 3.0 SUM WS(Y)= 5.3

DAY,MONTH AND HOUR 15111708 FLIGHT 1 RUN 14

TIME SEC	AZ(1) DEG	EL(1) DEG	AZ(2) DEG	EL(2) DEG	HT2 FT	HT1 FT	DH FT	R/R F/S	INT RR F/S	X FT	Y FT	WS(X) MPH	WS(Y) MPH	INT WSX MPH	INT WSY MPH	SWT=WSX MPH	SWT=WSY MPH
2.0	172.303	2.050	22.803	8.258	21	15	15	8	8	11	9	3.6	3.2	3.6	3.2	.6	.5
4.0	170.278	3.776	27.553	12.391	34	28	13	6	7	17	23	2.0	4.7	2.8	3.9	.8	1.0
6.0	168.753	4.890	30.655	14.603	42	36	8	4	6	21	34	1.3	3.6	2.3	3.8	.9	1.2
8.0	166.678	6.295	34.090	16.825	53	47	10	5	6	25	48	1.4	5.1	2.1	4.1	1.0	1.5
10.0	164.988	7.510	36.631	18.601	62	56	9	5	6	28	60	1.2	4.1	1.9	4.1	1.0	1.7
12.0	163.015	8.916	39.941	20.616	73	67	11	6	6	35	74	2.3	4.5	2.0	4.2	1.1	1.9
14.0	160.821	10.700	42.368	22.608	86	80	14	7	6	39	89	1.4	5.4	1.9	4.4	1.2	2.1
16.0	158.263	13.291	46.240	25.966	108	102	22	11	6	50	107	3.6	5.9	2.1	4.6	1.4	2.4
18.0	156.063	14.783	48.900	27.310	122	116	13	7	6	57	123	2.7	5.3	2.2	4.6	1.5	2.6
20.0	153.548	16.310	50.916	28.066	138	129	14	7	6	63	141	2.0	6.4	2.2	4.8	1.5	2.8
22.0	151.446	17.751	53.235	29.216	150	144	15	7	7	72	157	3.0	5.4	2.2	4.9	1.6	3.0
24.0	149.701	19.016	54.843	30.103	163	157	13	7	7	79	170	2.3	4.6	2.2	4.8	1.7	3.1
30.0	144.021	21.866	61.373	31.736	204	197	40	7	7	114	218	3.9	5.4	2.6	5.0	2.0	3.6
32.0	142.358	22.803	62.895	32.233	217	211	14	7	7	124	234	3.4	5.2	2.6	5.0	2.1	3.7
34.0	141.328	23.683	64.220	32.991	231	225	14	7	7	133	244	3.1	3.5	2.7	4.9	2.2	3.8
42.0	135.085	27.641	68.461	35.151	301	295	70	9	7	172	310	3.3	5.6	2.8	5.0	2.4	4.1
44.0	133.818	28.196	69.280	35.323	314	308	14	7	7	181	325	3.1	5.2	2.8	5.0	2.4	4.1
54.0	127.951	31.066	72.878	36.571	396	390	81	8	7	231	406	3.4	5.5	2.9	5.1	2.4	4.1

SUM WS(X)= 2.4 SUM WS(Y)= 4.1

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Army Electronics Research and Development Laboratory
Fort Monmouth, New Jersey

DOUBLE THEODOLITE-ANEMOMETER WIND-MEASURING SET
by Donald E. Johnson
August 1962, 20 p. incl. tables, 1 ref.
(USAELRDL Technical Report 2287)
(DA Task 3A99-27-005-12) Unclassified Report

This report discusses the feasibility of combining a double theodolite wind-measurement with an anemometer wind-measurement, with the intent of having the combination form a practical wind-measuring system. The wind data from such a combination would be applied to the correction of a rocket-launcher setting before firing a free missile.

A theoretical discussion and supporting data are presented to show that this combination of equipment is not feasible for the formation of a practical system.

1. Double theodolite wind-measurement
2. Anemometer wind-measurement
3. Rocket-launcher setting
4. Free missile

I. Johnson, Donald E.
II. Army Electronics Research and Development Laboratory, Fort Monmouth, New Jersey.
III. DA Task 3A99-27-005-12.

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